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# The energy requirements and carbon dioxide emissions of tourism industry of Western China: A case of Chengdu city

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ABSTRACT

Chengdu, the capital city of Sichuan province in western China is the gateway to Tibet. It is also the major habitat for giant panda and the principal city with the largest total tourism economic output in western China. The energy requirement of tourism industry is calculated by combining the 7 energy intensities with tourist consumption data from the Chengdu Domestic Tourist Expenditure Survey in which over 50,000 tourists were involved during 1999–2004. The carbon dioxide emissions of tourism industry are calculated based on the method introduced by IPCC report. Then, decomposition analysis was used to identify key factors causing the change of carbon emission. From 1999 to 2004, the energy consumption and carbon dioxide emission of tourism industry in Chengdu increased from $1.8 \times 10^7$ GJ to $2.3 \times 10^7$ GJ and from $1.7 \times 10^6$ tons to $2.1 \times 10^6$ tons, respectively. The indirect energy requirements and indirect $CO_2$ emissions dominate the total energy consumptions and total $CO_2$ emissions, with an overwhelming percentage of over 90%. The transportation is the major contributor for energy consumption and carbon emission of tourism industry. The relative importance of the transportation and shopping tends to increase while the food and entertainment tends to decrease. Among the five factors affecting energy consumption and carbon dioxide emission in tourism, energy intensity, expenditure size and the industry size are generally found to be principal drivers of emission growth, whereas energy share and consumption structure are not found to have a sizable influence on the growth of tourism industry emissions. In addition, the energy intensity has a negative effect on the increase of $CO_2$ levels while the expenditure size and the industry size have a positive effect on it.



**Contents**



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## 1. Introduction

The increasing concentrations of $CO_2$ in the atmosphere will result in significant changes in the world's climate during the next century [1]. The use of fossil energy source is the most important cause of $CO_2$ emissions [2]. Many governments around the world, including the China, are beginning to address issues of energy requirements and carbon emissions from all sectors of their economics [3–6]. Since the late 1978s, China has undergone one of the highest tourism growth rates in the world and this trend is expected to continue in the future [7]. By 2008, the total number of visitors was 1.8 billion, of which 1.7 billion were domestic tourists and 100 million were inbound tourists [8]. The tourism industry brings economic benefits to the country, but there are usually energy consumption and carbon dioxide emission associated with it [9,10]. A tourist not only uses direct energy in the form of petrol, gas and coal, but he (she) also uses indirect energy embodied in consumer goods such as services, food and products [11]. The existing literature of fossil energy consumption and carbon emission of tourism industry has focused much on direct energy consumption and direct emission; there is little consideration of the indirect energy consumption and indirect emission. Some researchers estimated that the direct energy requirement of households to be about half of the total energy requirement. This means that the indirect energy requirement and indirect carbon emission can be all but neglected [12–14].

It is difficult to analyze in detail all the aspects of the demand for goods and services associated with the activity of visitors because the travel and tourism industry today is the world's largest and most diverse business sector. The input–output analysis, a useful analytical framework developed by Wassily Leontief (1936), has been widely used in computing carbon dioxide emissions from energy consumption for different sector in recent decades [15,16]. With the help of input–output analysis, it can be relatively easily to compute the cumulative energy inputs of sectors related to the tourism industry in a fairly accurate way regardless of the length and complexity of the production process [17,18].

To study the impacts of factors (e.g. structural change and energy intensity change) on the energy use and the carbon emissions in industries in the late 1970s, index decomposition analysis has been introduced and extended. Since 1990, an increasing number of studies on energy-related carbon dioxide emissions decomposition have been reported [19,20]. After a comprehensive comparison of different IDA methods, Ang recommended the multiplicative and additive LMDI I method due to their theoretical foundation, adaptability, ease of use and result interpretation, and some other desirable properties [21].

This paper analyzes tourists' total energy consumption, carbon dioxide emissions and the impacts of a variety of factors on the total carbon emissions of the tourism industry. This analysis will increase understanding of the energy consumption and carbon emission of the tourism industry. Moreover, we aim to help the policy makers to design energy policies that enhance low carbon development of tourism industry for China.

## 2. Study area

Chengdu, the capital city of Sichuan province, is located between latitude 30°05′N and 31°26′N and longitude 102°54′E and 104°53′E, with an area of 12,121 km$^2$ and with a population of 11 million. The climate in Chengdu has distinct four seasons of subtropical monsoon climate type, with average annual temperature of 16.7 °C, mean annual sunshine time of 1071 h, average annual rainfall is 945.6 mm. Chengdu is one of the most important economic centers in western China and the gateway to Tibet. The area is home to a large amount of rare and endangered flora and fauna, including giant panda, golden monkey, gingko, Chinese dove tree and so on. In addition, with its long history of over 2300 years, Chengdu is also rich in cultural and historic resources. Among the numerous scenic spots and historical sites, the two UNESCO World Heritage Sites (the world natural heritage, Sichuan Giant Panda Habitat and the world cultural heritage, Qingcheng Mountain and Dujiangyan Irrigation System) are considered as the pearl on the crown of the city. The unique geological formation and rich natural and cultural heritage

**Table 1**
Direct primary energy intensities of non-energy products.

| Sectors (MJ/10$^3$ yuan) | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|---|---|
| Food | 60.15 | 51.54 | 44.16 | 37.84 | 32.42 | 27.78 | 27.11 | 26.45 | 25.81 |
| Accommodation | 48.59 | 46.49 | 44.49 | 42.57 | 40.73 | 38.97 | 41.46 | 43.9 | 46.92 |
| Transportation | 46.07 | 43.6 | 41.26 | 39.05 | 36.95 | 34.97 | 33.48 | 32.05 | 30.68 |
| Shopping | 15.00 | 15.26 | 15.53 | 15.81 | 16.09 | 16.37 | 14.01 | 12.00 | 10.27 |
| Entertainment | 58.33 | 52.13 | 46.6 | 41.65 | 37.22 | 33.27 | 31.9 | 30.6 | 29.34 |
| Postal services | 8.97 | 11.01 | 13.5 | 16.57 | 20.33 | 24.94 | 24.12 | 23.32 | 21.08 |
| Other services | 58.08 | 55.66 | 53.35 | 51.13 | 49.00 | 46.96 | 48.09 | 49.24 | 50.43 |

**Table 2**
Indirect primary energy intensities of non-energy products.

| Sectors (MJ/10$^3$ yuan) | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|---|---|
| Food | 379.93 | 350.25 | 322.89 | 297.66 | 274.41 | 252.97 | 253.58 | 265.3 | 271.69 |
| Accommodation | 448.51 | 411.78 | 378.05 | 347.09 | 318.66 | 292.56 | 310.3 | 329.12 | 349.09 |
| Transportation | 885.52 | 800.12 | 722.96 | 653.23 | 590.24 | 533.3 | 512.39 | 492.3 | 472.99 |
| Shopping | 411.72 | 427.45 | 443.78 | 460.73 | 478.33 | 496.62 | 463.5 | 432.59 | 403.73 |
| Entertainment | 627.08 | 582.48 | 541.06 | 502.58 | 466.83 | 433.62 | 394.66 | 359.2 | 326.92 |
| Postal services | 22.47 | 25.58 | 29.12 | 33.15 | 37.73 | 42.95 | 43.98 | 45.02 | 46.1 |
| Other services | 1144.14 | 1114.83 | 1086.27 | 1058.44 | 1031.32 | 1004.88 | 1007.17 | 1051.12 | 1075.04 |

**Table 3**
The energy consumption structure in China.

| Energy types | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|
| Coal | 69.1 | 67.8 | 66.7 | 66.3 | 68.4 | 68 |
| Oil | 22.6 | 23.2 | 22.9 | 23.4 | 22.2 | 22.3 |
| Natural gas | 2.1 | 2.4 | 2.6 | 2.6 | 2.6 | 2.6 |
| Hydropower, nuclear power, wind power | 6.2 | 6.7 | 7.9 | 7.7 | 6.8 | 7.1 |

of the city have long lured tourists from both China and abroad. According to the Chengdu Bureau of Statistics, the total tourists arrivals in 2008 were 41.5 million, of witch over 95% were domestic. The tourism receipts grew to 37.5 trillion yuan in 2008. The receipts of tourism industry account for 18.21% of GDP of Chengdu, it means that the tourism industry has become a vital sector of the city. Nowadays, Chengdu has become not only the most relaxing city in China, but also the principal city with the largest total tourism economic output in western China.

## 3. Materials and methods

### 3.1. Material

In our research, data concerning daily expenditure were collected by questionnaire process from domestic tourists from 1999 to 2004. The Chengdu Domestic Tourist Expenditure Survey (CDTES) is based on a random sample consisting of over 50,000 tourists whose expenditure was recorded in a detailed manner. The CDTES definitions are based on those provided by the world tourism organization and therefore interviews are conducted with Chinese people who have traveled for purposes including holiday, visiting friends and relatives, business and education. These tourists must have been away from home for more than 6 h and 10 km. The sample is selected from domestic tourists in the twelve districts and countries of Chengdu city. The sample size is determined by the 0.3‰ of the total arrivals of the tourism industry. In addition, the overnight visitors were interviewed in the hotel and the day visitors' survey was conducted at the scene pots. The total consumption of the tourists was divided into 8 basic consumption categories: transportation, food, accommodation, shopping, recreation, entertainment, postal services and the others. Data about socio-economic development, tourist arrivals are selected from the yearbooks of Chengdu Bureau of Tourism and the energy structure is selected from China energy statistical yearbook.

### 3.2. Methods

#### 3.2.1. The energy requirements of tourism industry

The total energy requirements of tourism industry can be calculated, according to formula (1):

$$E^{Total} = E^{Direct} + E^{Indirect} \quad (1)$$

where $E^{Total}$ represents the total energy requirements of tourism industry; $E^{Direct}$ is the direct energy requirements; $E^{Indirect}$ is the indirect energy requirements.

The direct energy requirements can be calculated by multiplying the energy intensity of the tourism sectors with the visitors' expenditure:

$$E^{Direct} = \sum_{i=1}^{7} e_i^{Direct} \times s_i \quad (2)$$

$e_i^{Direct}$ is the direct energy intensity of sector $i$ and $s_i$ the visitors' expenditure of category $i$. Parameter $i$ refers to types of tourism sector and expenditure category: transportation, food, accommodation, shopping, entertainment, postal services and the other services. The direct energy intensities of the sectors were based on Liu [22] (Table 1).

The indirect energy requirements can be computed as in Eq. (3):

$$E^{Indirect} = \sum_{i=1}^{7} e_i^{Indirect} \times s_i \quad (3)$$

where $e_i^{Indirect}$ is the indirect energy intensity of sector $i$. The indirect energy intensities of the sectors were based on [22] (Table 2).

#### 3.2.2. The carbon oxide emission of tourism industry

The total $CO_2$ emission of tourism industry can be calculated by formula (4):

$$C^{total} = C^{direct} + C^{indirect} \quad (4)$$

where $C^{Total}$ is the total $CO_2$ emission of tourism industry; $C^{Direct}$ is the direct $CO_2$ emission; $C^{Indirect}$ is the indirect $CO_2$ emission.

According to the IPCC report 2007, Eqs. (5) and (6) were formulated to calculate the direct and indirect carbon dioxide emissions of the tourism industry. Tables 3 and 4 show detailed coefficients:

$$C^{Direct} = \sum_{j=1}^{3} E^{Direct} \times p_j \times C_{cont,j} \times O_j \times \frac{44}{12} \times POP \quad (5)$$

$C^{Direct}$ is the direct carbon dioxide emissions of the tourism industry $p_j$ is the percentage of the primary energy consumption in China; $C_{cont,j}$ is the carbon coefficient of the primary energy; $O_j$ is the oxidation efficiency of primary energy when it is burned (%); $POP$ is the total number of the tourists; parameter $j$ refers to types of primary energy: coal, natural gas and crude oil:

$$C^{Indirect} = \sum_{j=1}^{3} E^{Indirect} \times p_j \times C_{cont,j} \times O_j \times \frac{44}{12} \times POP \quad (6)$$

where $C^{Indirect}$ is the indirect carbon dioxide emission of the tourism industry.

#### 3.2.3. The Kaya identity and decomposition for carbon dioxide emissions

The Kaya identity was developed by Japanese energy economist Yoichi Kaya [23]. The identity is an equation relating factors that determine the level of human impact on $CO_2$ emissions. By extension, the Kaya identity can be used to organize discussion of the primary driving forces of $CO_2$ emissions from tourism industry. The extended Kaya identity is expressed in the form:

$$C = \sum_i \sum_j \left( \frac{C_{ij}}{PE_{ij}} \cdot \frac{PE_{ij}}{PE_i} \cdot \frac{PE_i}{S_i} \cdot \frac{S_i}{S} \cdot \frac{S}{POP} \cdot POP \right) \quad (7)$$

**Table 4**
Default carbon content of the primary energy.

| Energy types | Default carbon content (kg/GJ) | Low | High |
|---|---|---|---|
| Natural gas | 15.3 | 14.8 | 15.9 |
| Coal | 26.8 | 25.8 | 27.5 |
| Crude oil | 20 | 19.4 | 20.6 |

**Table 5**
The direct energy requirements of tourism industry in Chengdu during 1999–2004.

| Sectors (GJ) | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|
| Food | 264,376.6 | 363,951 | 329,698.44 | 451,362.91 | 301,416.3 | 448,861.46 |
| Accommodation | 405,583.6 | 393,048 | 405,028.6 | 497,987.83 | 358,571.66 | 593,873.3 |
| Transportation | 312,046.85 | 204,156 | 202,256.32 | 207,284.27 | 146,158.47 | 222,179.99 |
| Shopping | 331,372.62 | 297,886.5 | 213,091.48 | 236,214.19 | 179,712.36 | 270,731.63 |
| Entertainment | 89,929.27 | 98,262 | 88,487.14 | 145,773.09 | 85,590.86 | 114,466.1 |
| Postal services | 7472.63 | 19,318.5 | 11,351.12 | 27,244.68 | 17,061.3 | 25,722.72 |
| Other services | 97,917.26 | 191,754 | 64,495 | 56,455.47 | 65,686.01 | 104,498.55 |
| Total | 1,508,698.84 | 1,568,376 | 1,314,408.1 | 1,622,322.45 | 1,154,196.95 | 1,780,333.76 |

$C$ represents $CO_2$ emissions from tourism industry; $C_{ij}$ is $CO_2$ emissions of the $i$ type of tourism sector and expenditure category with the $j$ kind of primary energy burning; $PE_{ij}$ is the energy requirements of the $i$ type of types of tourism sector and expenditure category with the $j$ kind of primary energy burning; $PE_i$ is the energy requirement of the $i$ type of primary energy; $S_i$ is the expenditure of $i$ type of category; $S$ is the total expenditure of the tourist; $POP$ is the total number of tourist arrivals:

Let $f_{ij} = \frac{C_{ij}}{PE_{ij}}$, $m_{ij} = \frac{PE_{ij}}{PE_i}$, $t_i = \frac{PE_i}{S_i}$, $s_i = \frac{S_i}{S}$, $g = \frac{S}{POP}$, $p = pop$, Eq. (7) can also be rewritten as:

$$C = \sum_i \sum_j (f_{ij} \times m_{ij} \times t_i \times s_i \times g \times p) \quad (8)$$

The emissions of tourism industry can be decomposed in to six main driving factors: emission factor effect ($f_{ij}$); energy mix effect ($m_{ij}$), energy intensity effect ($t_i$); consumption structure effect ($s_i$); average expenditure effect (g) and total arrivals scale effect ($p$).

In this section, we adopt the additive LMDI to decompose tourism industry $CO_2$ emissions growth to the contributing factors. The different change of $CO_2$ emissions from year 0 to year $T$ can be calculated by Eq. (9):

$$\Delta C_{tot} = C^T - C^0 \quad (9)$$

$\Delta C_{tot}$ is the total different change from year 0 to year $T$; $C^T$ is the emission in year $T$; $C^0$ is the emission in year 0. The different change $\Delta C_{tot}$ may be attributed to the following determinant factors: emission factor effect ($\Delta C_{f_{ij}}$), energy mix effect ($\Delta C_{m_{ij}}$), energy intensity effect ($\Delta C_{t_i}$), consumption structure effect ($\Delta C_{s_i}$), expenditure size effect ($\Delta C_g$) and industry size effect ($\Delta C_p$). In additive decomposition, the total difference $\Delta C_{tot}$ is decomposed into its components as illustrated in Eq. (10):

$$\Delta C_{tot} = C^T - C^0 = \Delta C_{f_{ij}} + \Delta C_{m_{ij}} + \Delta C_{t_i} + \Delta C_{s_i} + \Delta C_g + \Delta C_p \quad (10)$$

Each explanatory factor shown in Eq. (10) can be calculated through Eqs. (11)–(16), based on the general formula of LMDI I presented by Ang (2005).

emission factor effect:

$$\Delta C_{f_{ij}} = \sum_i \sum_j \left( \frac{C_{ij}^T - C_{ij}^0}{\ln C_{ij}^T - \ln C_{ij}^0} \cdot \ln \frac{f_{ij}^T}{f_{ij}^0} \right) \quad (11)$$

energy mix effect:

$$\Delta C_{m_{ij}} = \sum_i \sum_j \left( \frac{C_{ij}^T - C_{ij}^0}{\ln C_{ij}^T - \ln C_{ij}^0} \cdot \ln \frac{m_{ij}^T}{m_{ij}^0} \right) \quad (12)$$

energy intensity effect:

$$\Delta C_{t_i} = \sum_i \sum_j \left( \frac{C_{ij}^T - C_{ij}^0}{\ln C_{ij}^T - \ln C_{ij}^0} \cdot \ln \frac{t_i^T}{t_i^0} \right) \quad (13)$$

consumption structure effect:

$$\Delta C_{s_i} = \sum_i \sum_j \left( \frac{C_{ij}^T - C_{ij}^0}{\ln C_{ij}^T - \ln C_{ij}^0} \cdot \ln \frac{s_i^T}{s_i^0} \right) \quad (14)$$

expenditure size effect:

$$\Delta C_g = \sum_i \sum_j \left( \frac{C_{ij}^T - C_{ij}^0}{\ln C_{ij}^T - \ln C_{ij}^0} \cdot \ln \frac{g^T}{g^0} \right) \quad (15)$$

industry size effect:

$$\Delta C_p = \sum_i \sum_j \left( \frac{C_{ij}^T - C_{ij}^0}{\ln C_{ij}^T - \ln C_{ij}^0} \cdot \ln \frac{p^T}{p^0} \right) \quad (16)$$

As the carbon coefficients is constant, the emission factor effect ($\Delta C_{f_{ij}}$) is always 0, the Eq. (10) can be expressed as:

$$\Delta C_{tot} = \Delta C_{m_{ij}} + \Delta C_{t_i} + \Delta C_{s_i} + \Delta C_g + \Delta C_p \quad (17)$$

## 4. Results

### 4.1. The energy requirements of tourism industry

#### 4.1.1. The direct energy requirements of tourism industry

Between 1999 and 2004, the direct energy requirements of tourism industry for Chengdu have increased from 1,508,698.84 GJ to 1,780,333.76 GJ. Among it, the direct energy requirement in 2003 is the lowest while that of 2004 is the highest (Table 5).

In terms of the direct energy consumption structure, accommodation is the largest contributor during 1999–2004, while postal service is the smallest. Besides, the percentage of the direct energy consumption of accommodation and transportation is increasing, while that of entertainment and food and other forms is decreasing; the percentage of the direct energy consumption of postal services and shopping is relatively constant (Fig. 1).

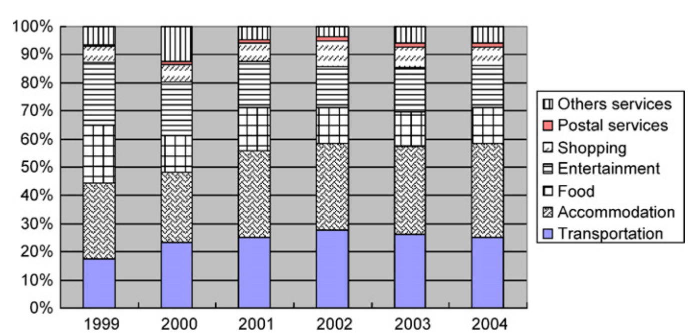



**Fig. 1.** The structure of direct energy requirements of tourism industry in Chengdu from 1999 to 2004.

**Table 6**
The indirect energy requirements of tourism industry in Chengdu during 1999–2004.

| Sectors (GJ) | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|
| Food | 4,630,455.69 | 6,086,520 | 5,265,887.76 | 6,883,354.61 | 4,613,091.17 | 6,893,367.43 |
| Accommodation | 3,445,914.52 | 3,203,770.5 | 3,167,994.4 | 3,738,419.63 | 2,683,742.49 | 4,451,316.7 |
| Transportation | 2,281,214.48 | 1,606,059 | 1,712,213.26 | 1,886,904.81 | 1,366,325.78 | 2,229,838.29 |
| Shopping | 3,847,890.64 | 3,593,718 | 2,673,704.72 | 3,078,368.08 | 2,223,940.46 | 3,178,042.06 |
| Entertainment | 2,568,782.01 | 2,864,146.5 | 2,631,911.96 | 4,422,345.39 | 2,830,469.67 | 4,121,101.28 |
| Postal services | 16,491.33 | 38,875.5 | 21,154.36 | 47,186.66 | 30,994.7 | 49,516.24 |
| Other services | 1,994,162.3 | 3,971,979 | 1,359,554.6 | 1,209,720.01 | 1,373,434.65 | 2,231,445.96 |
| Total | 18,784,910.98 | 21,365,068.5 | 16,832,421.06 | 21,266,299.2 | 15,121,998.9 | 23,154,627.94 |

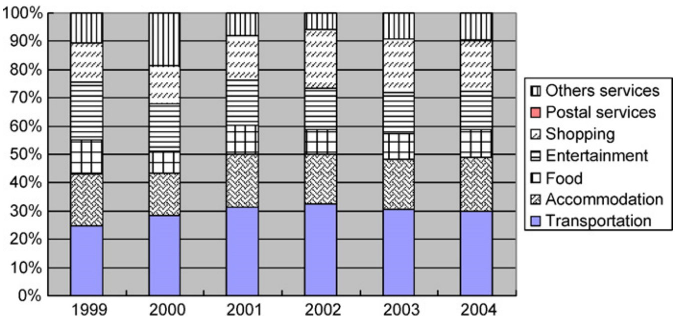



**Fig. 2.** The structure of indirect energy requirements of tourism industry in Chengdu from 1999 to 2004.

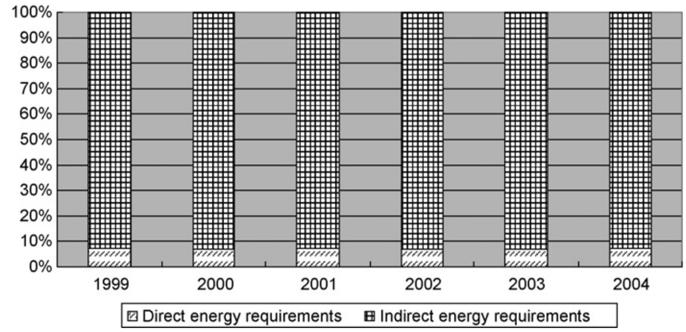



**Fig. 3.** The share of direct and indirect energy requirements of tourism industry in Chengdu from 1999 to 2004.

### 4.1.2. The indirect energy requirements of tourism industry

From 1999 to 2004, the indirect energy requirements of tourism industry in Chengdu grew from 18,784,910.98 GJ to 23,154,627.94 GJ. Among it, the indirect energy consumption of 2003 is the lowest while that of 2004 is the highest (Table 6).

In terms of indirect energy consumption structure of tourism industry, transportation is the largest contributor, while postal service is the smallest. Besides, as to structure change trend of the indirect energy requirement, the percentage of the indirect energy consumption of shopping and transportation is increasing, while that of entertainment and food is decreasing; the percentage of other forms of consumption remains about the same (Fig. 2).

### 4.1.3. The total energy requirements of tourism industry

The amount of the total energy consumption in tourism industry during the period from 1999 to 2004 increased from 18,784,910.98 GJ to 23,154,627.94 GJ. Among it, the total energy requirement in 2003 is the lowest while that of 2004 is the highest. In addition, indirect energy consumption dominates the total energy consumption, with an overwhelming percentage of over 90% (Table 7, Fig. 3).

Just like the indirect energy consumption, transportation is the largest contributor to the total energy consumption from 1999 to 2004, while postal service is the smallest. In addition, the percentage of the total energy consumption of shopping and transportation is increasing, while that of entertainment and food is decreasing; the percentage of other forms of energy consumption is relatively constant (Fig. 4).

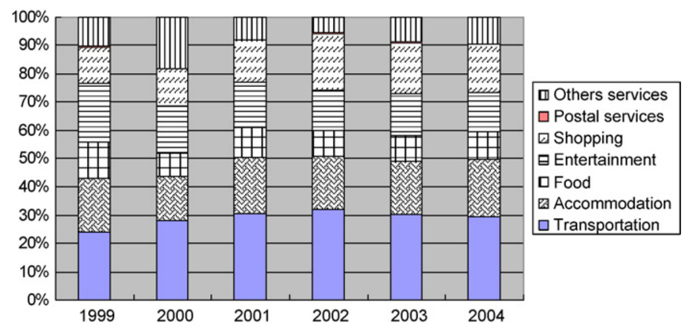



**Fig. 4.** The structure of total energy requirements of tourism industry in Chengdu from 1999 to 2004.

## 4.2. The carbon oxide emission of tourism industry

### 4.2.1. The direct carbon dioxide emission of tourism industry

The amount of direct carbon dioxide emission from tourism industry during the period from 1999 to 2004 increased from 121,108.19 tons to 141,796.49 tons. Among it, the direct emission of 2003 is the lowest while that of 2004 is the highest (Table 8).

**Table 7**
The total energy requirements of tourism industry in Chengdu during 1999–2004.

| Sectors (GJ) | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|
| Food | 463,0455.69 | 6,086,520 | 5,265,887.76 | 6,883,354.61 | 4,613,091.17 | 6,893,367.43 |
| Accommodation | 3,445,914.52 | 3,203,770.5 | 3,167,994.4 | 3,738,419.63 | 2,683,742.49 | 4,451,316.7 |
| Transportation | 2,281,214.48 | 1,606,059 | 1,712,213.26 | 1,886,904.81 | 1,366,325.78 | 2,229,838.29 |
| Shopping | 3,847,890.64 | 3,593,718 | 2,673,704.72 | 3,078,368.08 | 2,223,940.46 | 3,178,042.06 |
| Entertainment | 2,568,782.01 | 2,864,146.5 | 2,631,911.96 | 4,422,345.39 | 2,830,469.67 | 4,121,101.28 |
| Postal services | 16,491.33 | 38,875.5 | 21,154.36 | 47,186.66 | 30,994.7 | 49,516.24 |
| Other services | 1,994,162.3 | 3,971,979 | 1,359,554.6 | 1,209,720.01 | 1,373,434.65 | 2,231,445.96 |
| Total | 18,784,910.98 | 21,365,068.5 | 16,832,421.06 | 21,266,299.2 | 15,121,998.9 | 23,154,627.94 |

**Table 8**
The direct $CO_2$ emissions of tourism industry in Chengdu during 1999–2004.

| Sector (ton) | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|
| Food | 22,675.58 | 31,005 | 27,603.86 | 37,917.86 | 25,591.95 | 37,941.01 |
| Accommodation | 34,786.4 | 33,390 | 33,795.38 | 41,850.08 | 30,425.99 | 50,159.3 |
| Transportation | 26,798.41 | 17,410.5 | 17,026.68 | 17,414.13 | 12,511.62 | 18,970.51 |
| Shopping | 28,344.47 | 25,281 | 17,800.62 | 19,661.11 | 15,355.17 | 22,828.91 |
| Entertainment | 7730.31 | 8347.5 | 7481.42 | 12,077.54 | 7393.23 | 9646.02 |
| Postal services | 773.03 | 1669.5 | 1031.92 | 2246.98 | 1421.78 | 2250.74 |
| Other services | 8503.34 | 16,218 | 5417.58 | 4774.84 | 5687.1 | 9002.95 |
| Total | 121,108.19 | 117,103.5 | 104,739.88 | 131,167.69 | 92,699.73 | 141,796.49 |

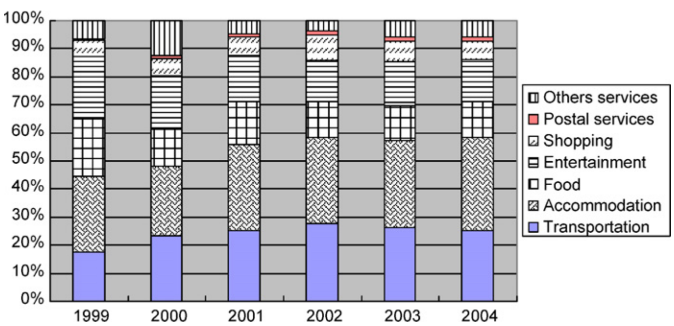



**Fig. 5.** The structure of direct $CO_2$ emission of tourism industry in Chengdu from 1999 to 2004.

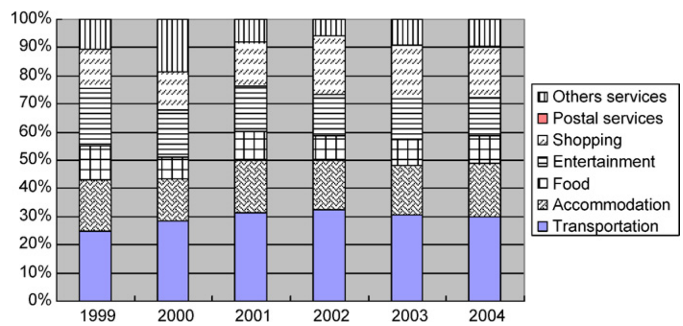



**Fig. 6.** The structure of indirect $CO_2$ emission of tourism industry in Chengdu from 1999 to 2004.

In terms of direct $CO_2$ emission structure of tourism industry, accommodation is the largest contributor from 1999 to 2004, while postal service is the smallest. Besides, the percentage of direct $CO_2$ emission from accommodation and transportation is increasing, while that of entertainment, food and other forms is decreasing; the percentage of the postal service and shopping remains about the same (Fig. 5).

### *4.2.2. The indirect carbon dioxide emission of tourism industry*

From 1999 to 2004, the indirect $CO_2$ emission from domestic tourism industry increased from 1,608,677.51 tons in 1999 to 1,960,071.26 tons in 2004. Among it, the indirect emission of 2003 is the lowest while that of 2004 is the highest (Table 9).

In terms of indirect $CO_2$ emission structure of tourism industry, transportation is the largest contributor from 1999 to 2004, while postal service is the smallest. Besides, as to structure change trend of the indirect $CO_2$ emission, the percentage of the indirect $CO_2$ emission of shopping and transportation is increasing, while that of entertainment and food is decreasing; the percentage of other forms of consumption remains about the same (Fig. 6).

### *4.2.3. The total carbon dioxide emission of tourism industry*

The results show that a large amount of $CO_2$ is produced by tourists' consumption. From 1999 to 2004, the $CO_2$ emission caused by tourism industry increased from 1,738,289.04 tons in 1999 to 2,110,870.71 tons in 2004. In addition, indirect emission dominates the total emission, with an overwhelming percentage of over 90% (Table 10, Fig. 7).

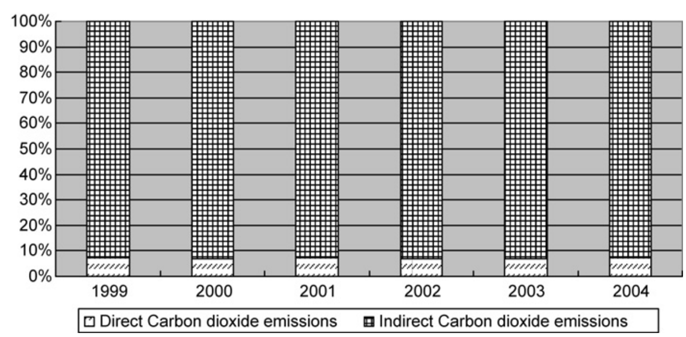



**Fig. 7.** The share of direct and indirect $CO_2$ emission of tourism industry in Chengdu from 1999 to 2004.

In terms of total $CO_2$ emission structure of tourism industry, transportation is the largest contributor from 1999 to 2004, while postal service is the smallest. In addition, the percentage of total $CO_2$ emission from transportation and shopping is increasing, while that of entertainment, food and other form of service is decreasing; the percentage of accommodation and postal service is relatively constant (Fig. 8).

**Table 9**
The indirect $CO_2$ emission of tourism industry in Chengdu during 1999–2004.

| Sector (ton) | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|
| Food | 396,564.9 | 516,829.5 | 440,887.82 | 576,632.27 | 391,841.19 | 583,584.21 |
| Accommodation | 295,040.17 | 272,128.5 | 265,203.44 | 313,173.4 | 228,052.71 | 376,837.85 |
| Transportation | 195,319.17 | 136,422 | 143,436.88 | 158,131.5 | 116,016.84 | 188,740.46 |
| Shopping | 329,568.88 | 305,280 | 223,926.64 | 257,841.41 | 188,811.72 | 269,123.96 |
| Entertainment | 220,056.16 | 24,3270 | 220,314.92 | 370,471.49 | 240,279.98 | 348,864.39 |
| Postal services | 1288.39 | 3339 | 1805.86 | 3932.22 | 2559.2 | 4179.94 |
| Other services | 170,839.85 | 337,239 | 113,769.18 | 101,395.15 | 116,585.55 | 188,740.46 |
| Total | 1,608,677.51 | 1,814,508 | 1,409,344.74 | 1,781,577.44 | 1,284,147.18 | 1,960,071.26 |

**Table 10**
The total $CO_2$ emission of tourism industry in Chengdu during 1999–2004.

| Sector (ton) | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|
| Food | 419,240.48 | 547,834.5 | 468,491.68 | 614,550.12 | 417,433.14 | 621,525.22 |
| Accommodation | 329,826.56 | 305,518.5 | 298,998.82 | 355,023.47 | 258,478.7 | 426,997.15 |
| Transportation | 222,117.57 | 153,832.5 | 160,463.56 | 175,545.63 | 128,528.46 | 207,710.96 |
| Shopping | 357,913.35 | 330,561 | 241,727.26 | 277,502.52 | 204,166.89 | 291,952.87 |
| Entertainment | 227,786.47 | 251,617.5 | 227,796.34 | 382,549.03 | 247,673.21 | 358,510.41 |
| Postal services | 2061.42 | 5008.5 | 2837.78 | 6179.21 | 3980.97 | 6430.68 |
| Other services | 179,343.19 | 353,457 | 119,186.76 | 106,169.99 | 122,272.65 | 197,743.41 |
| Total | 1,738,289.04 | 1,947,829.5 | 1,519,502.2 | 1,917,519.97 | 1,382,534.01 | 2,110,870.71 |

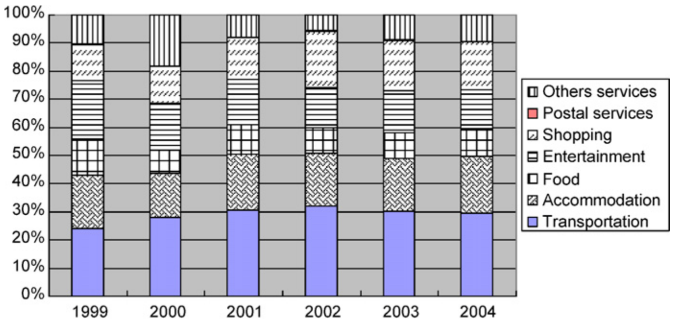



**Fig. 8.** The structure of total $CO_2$ emission of tourism industry in Chengdu from 1999 to 2004.

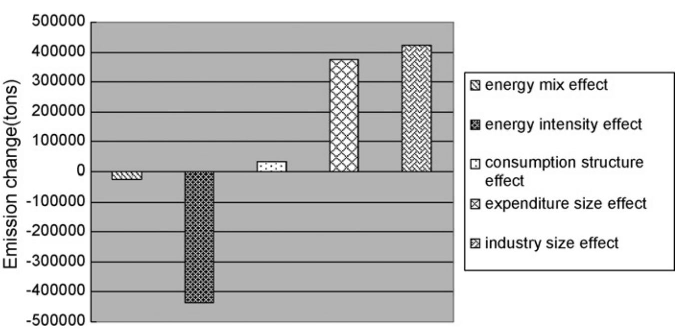



**Fig. 9.** Contribution of emission factor effect, energy mix effect, energy intensity effect, consumption structure effect, average expenditure effect and total arrivals scale effect to $CO_2$ change by tourism industry in Chengdu.

*4.2.4. Decomposition of carbon dioxide emission*

Fig. 9 presents the $CO_2$ emissions induced by the change of each one of the factors examined. During the period of 1999–2004, $CO_2$ emission from domestic tourists in Chengdu increased by 372,581.7 tons. In generally, the energy intensity and energy share have a negative effect on the increase of $CO_2$ levels while the expenditure, the consumption structure and the scale of the tourism industry have a positive effect on it. More specifically, the scale of the tourism industry effect is the major factor accounting for 113.42% of total emission increase followed by the expenditure effect which accounted for 100.6% of the total increase. The energy intensity effect is the major factor responsible for decrease in emissions accounting for −117.23% of the total decrease. The contribution of energy share and consumption structure is in general low. The decrease in the energy intensity cannot compensate the strong growth of expenditure and the scale of the industry.

## 5. Conclusion and discussion

The tourism sector is one of the sources of anthropogenic $CO_2$ emissions. Recently, tourism in China has witnessed a speedy growth. This paper presents direct and indirect energy requirements and carbon dioxide emissions of tourism industry in Chengdu during 1999–2004 and disaggregates the changes in total emissions during this period by energy mix, energy intensity, consumptions structure, expenditure size and industry size effect. The results are as follows:

From 1999 to 2004, the energy consumption and carbon dioxide emission of tourism industry in Chengdu increased from $1.8 \times 10^7$ GJ to $2.3 \times 10^7$ GJ and from $1.7 \times 10^6$ tons to $2.1 \times 10^6$ tons respectively. It is worth noticing that the indirect energy requirements and emissions dominate the total energy consumptions and emissions, with an overwhelming percentage of over 90%.

The transportation is the major contributor for energy consumption and carbon emission. The relative importance of the transportation and shopping tend to increase while the food and entertainment tend to decrease.

Among the five factors affecting energy consumption and carbon dioxide emission in tourism, energy intensity, expenditure size and industry size effect are generally found to be principal drivers of emission growth, whereas energy share and consumption structure are not found to have a sizable influence on the growth of tourism industry emissions. In addition, the energy intensity has a negative effect on the increase of $CO_2$ levels while the expenditure size and the industry size have a positive effect on it.

There are some limitations to this study. First, the energy intensity of consumption categories of tourism industry adopted is based on the input–output chart of corresponding period. However, the input–output chart of China is compiled every five years, so during the period of research, the energy intensity of corresponding year needs to be deduced, which causes uncertainty of the result. Second, this paper mainly discusses the domestic traveling, given the difficulty of obtaining the energy intensity of the countries involved in inbound tourism. Although the international tourism only accounts for 5% of the whole tourism industry in Chengdu, the missing of inbound tourism would cause underestimation of total requirements and total dioxide emissions.

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